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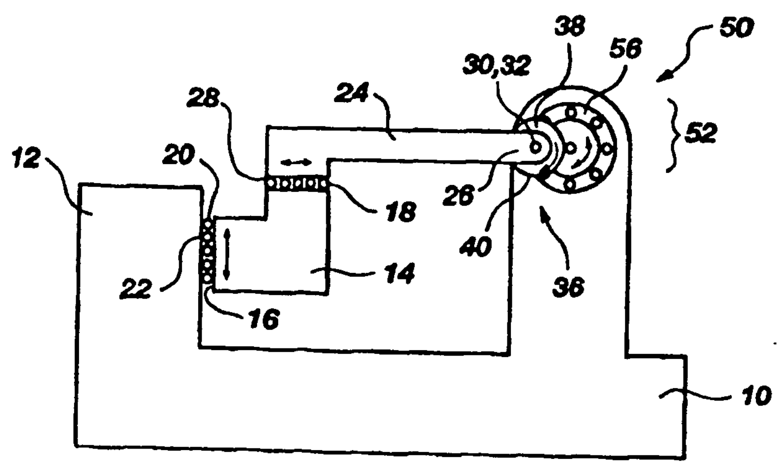
(54) Title: METHOD AND APPARATUS FOR FORMING CUTS IN CATHETERS, GUIDEWIRES AND THE LIKE

(57) Abstract

A catheter, guidewire or other cylindrical object cutting device which includes a base, at least one circular saw blade mounted on a spindle member, and a clamp for manipulating the object to be cut. The at least one circular saw blade is rotatably mounted on the spindle member. The spindle member is free to move vertically and horizontally with respect to the base to thereby control the location, size and depth of the cuts in a cylindrical objet disposed adjacent thereto. The clamp is able to hold the object to be cut, as well as rotate it to expose the entire circumference of the object to the saw blade. By releasing the clamp, a pinch roller can advance the object before the clamp is re-engaged to securely hold the object for cutting. Sensors are also provided to enable detection of wear of the saw blade so as to signal needed replacement or adjustment of the saw blade to compensate.



METHOD AND APPARATUS FOR FORMING CUTS IN CATHETERS, GUIDEWIRES AND THE LIKE

BACKGROUND

1. Field of the Invention

The present invention pertains to making precision cuts in catheters and guidewires. Specifically, a device for holding, advancing, rotating and then cutting a catheter or guidewire is provided which is able to manipulate the catheter or guidewire in two degrees of freedom to enable precision control of the location of the cuts. Various clamping mechanisms are provided for manipulating the catheter or guidewire, as well as mechanisms for wear detection of saw blades used to make the cuts resulting in controlled variation in mechanical properties.

2. State of the Art

Making cuts in catheters and guidewires requires precision in order to ensure reliability because of the medical applications in which they are used. However, it is also important to control costs of production so that costs to the health care industry can be minimized.

The state of the art is typified by such devices as grinding wires, wound coils, and lasers for making the cuts. But these devices often suffer from high cost or imprecise or difficult control mechanisms for properly

positioning both the device to make the cut and the cylindrical object to be cut.

What is needed is a method and apparatus for making cuts in catheters and guidewires which allows precise control of characteristics of the cuts. This entails precision holding, advancement and rotation of the generally cylindrical object while at least one saw blade is itself advanced to make the cut and retracted afterward.

Any discussion of documents, acts, materials, devices, articles or the like which has been included in the present specification is solely for the purpose of providing a context for the present invention. It is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present invention as it existed in Australia before the priority date of each claim of this application.

Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for forming precision cuts in catheters and guidewires. It also provides a method and apparatus for forming precision cuts in cylindrical objects.

The present invention also provides a method and apparatus for forming precision cuts by manipulating a cylindrical object in two degrees of freedom to control the parameters of the cuts.

Still further, the present invention provides a method and apparatus for holding, advancing and rotating a cylindrical object to be cut.

Yet further, the present invention provides a method and apparatus for increasing throughput of a device which forms cuts in cylindrical objects by providing multiple saw blades on a single cutting tool.

The present invention also provides a method and apparatus for detecting the extent of wear of a saw blade in order to more precisely control the position of the saw blade.

These and other preferred features of the present invention are realized in a preferred embodiment of a device for making cuts in a catheter, guidewire or other cylindrical or elongate objects.

According to a first aspect, the present invention consists in an a system configured for forming at least one precision cut in an elongate object, wherein the precision cut is generally transverse relative to a lengthwise axis of the elongate object, said system being characterized by:

a base;

a clamp, supported by the base and configured for selectively grasping and stabilizing the elongate member in a position suitable for cutting;

a first roller and a second roller comprising a pinch roller and feed roller, the first and second rollers being rotatably supported by the base, and configured to move the elongate object in a direction parallel to the lengthwise axis, said rollers being rotatable with the elongate object around the lengthwise axis of the elongate member;

a mechanism configured for rotating the elongate object, said mechanism being supported by the base and configured to rotate the first and second rollers;

a moveable member moveably carried by the base, and

a cutting means carried by the moveable member and moveable therewith toward and away from the elongate object, the system being configured for forming at least one precision cut in the elongate object at a desired location to a desired depth.

According to a further aspect, the present invention consists in an a system configured for forming at least one precision cut in an elongate object, said system being characterized by:

a base member;

a horizontally movable member having a spindle end, said horizontally moveable member being slidably carried by the base member;

a rotatable spindle disposed through the spindle end;

a circular saw blade, mounted on the spindle;

a drive means coupled to the spindle, configured for rotating the circular saw blade;

a clamping member coupled to the base member and a clamp disposed within to thereby enable the clamping member to engage the elongate object

while the circular saw blade makes the at least one precision cut therethrough; and

a pinch roller assembly configured for rotating the elongate object and for feeding the elongate object through the clamp towards the saw blade.

According to a still further aspect, the present invention consists in an a system for forming at least one precision cut in an elongate object, said system being characterized by:

a base member;

a vertically movable member slidably coupled to the base member;

a horizontally movable member having a spindle end and being slidably coupled to the vertically movable member;

at least one rotatable spindle disposed through the spindle end;

at least one circular saw blade disposed coaxially on the spindle;

a drive means coupled to the at least one spindle for rotating the at least one circular saw blade;

a clamping member coupled to the base member and a clamp disposed within to thereby enable the clamping member to engage the elongate object while the at least one circular saw blade makes the at least one precision cut therethrough; and

a pinch-roller manipulating means for rotating and feeding the elongate object through the clamp towards the saw blade.

Accordingly to a still further aspect, the present invention is a method of forming at least one precision cut in an elongate object, characterized by

providing a cutting device which includes a movable member having a spindle coupled thereto, a circular saw blade rotatably disposed on the spindle, a clamp for holding the elongate object while the circular saw blade makes an incision therein, and a manipulating means including a pinch roller assembly including a first roller and a second roller, and said manipulating means being configured for advancing the elongate object toward the clamp and rotating the elongate object, the method further characterized by the steps of:

(a) providing a length of the elongate object to the manipulating means for advancing the elongate object toward the clamp;
(b) causing the manipulating means to advance the elongate object toward the clamp by rotation of a roller of the pinch roller assembly;
(c) rotating the pinch roller assembly so as to rotate the elongate object about its lengthwise axis;
(d) engaging the clamp onto the elongate object;
(e) advancing the movable member and circular saw blade toward the elongate object;
(f) making the at least one precision cut in the elongate object; and
(g) retracting the moveable member and saw blade.

According to yet a still further aspect, the present invention consists in a method for forming at least one precision cut in an elongate object characterized by providing an apparatus including a clamp, a pinch roller manipulation means for rotating the elongate object about its lengthwise axis and for feeding the elongate object to the clamp, and a cutting device, wherein the cutting device makes at least one precision cut in the elongate

object which is generally transverse relative to a lengthwise axis thereof, said method characterized by:

(a) feeding the elongate object toward the clamp;

(b) manipulating the elongate object by at least one of the advancing and rotating motions enabled by the pinch roller manipulating means into a position which is suitable for making the at least one precision cut therein;

(c) engaging the clamp so as to securely hold the elongate object in the position which is suitable for cutting;

(d) making the at least one precision cut in the elongate object;

(e) disengaging the clamp; and

(f) repeating steps (a) through (e) until all desired cuts in the elongate object are completed.

Another preferred feature of the invention is the ability to make precision cuts by providing means for controlling the rotation and advancement of the object to be cut and movement of the saw blade spindle member. Sensors are also provided to enable detection of wear on the saw blade so as to signal needed replacement or adjustment of the location of the saw blade spindle member to compensate.

Another preferred feature is the ability to simultaneously make a plurality of cuts in the object. This is accomplished with a saw blade having a plurality of blades in parallel. Even more cuts can be made by providing more than one saw blade spindle member, where each is independently movable in two degrees of freedom.

Another preferred feature of the invention is to provide more than one spindle member so that blades can simultaneously make precision cuts at different locations along the length of the cylindrical object.

These and other features, advantages and alternative aspects of the present invention will become apparent to those skilled in the art from a

consideration of the following detailed description taken in combination with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A is a front elevational view of a preferred embodiment made in accordance with the principles of the present invention.

Figure 1B is a side elevational view of the invention shown in Figure 1A.

Figure 2 is an alternative embodiment of a vertically moving member shown reversed in orientation with respect to FIGS 1A and 1B.

Figure 3 is an alternative embodiment of a horizontally moving member shown reversed in orientation with respect to FIGS 1A and 1B.

Figure 4 is a block diagram of the preferred embodiment which shows a control means and sensor means for controlling position determination and movement of components.

Figure 5 is a block diagram showing signals which pass between components when using an electrical conduction sensor.

Figure 6 is a block diagram showing signals which pass between components when using a mechanical drag detection sensor.

Figure 7 is a block diagram showing signals which pass between components when using a rotation detector sensor.

Figure 8 is a block diagram showing signals which pass between components when using an optical detection sensor.

Figure 9A is a front elevational view of an alternative embodiment for the clamping means.

Figure 9B is a side elevational view of the alternative embodiment for the clamping means of FIG. 9A.

Figure 10 is an alternative saw blade assembly which can be used in all embodiments of the present invention.

Figure 11A is a top elevational view of an alternative clamping device.

Figure 11B is a side elevational view of the alternative clamping device of FIG. 11B.

Figure 12 is an alternative embodiment which uses two saw blade assemblies to simultaneously make incisions in the catheter.

DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made to the drawings in which the various elements of the present invention will be given numerical designations and in which the invention will be discussed so as to enable one skilled in the art to make and use the invention.

The present invention is illustrated in FIGS. 1A and 1B. FIG. 1A is a front view of the preferred embodiment of the invention, and shows the system for forming precision cuts in a catheter, a guidewire, or other cylindrical objects. For purposes of keeping in mind the intended use of the present invention, a catheter will be referred to as the object being cut, although any cylindrical object can be substituted for the catheter. However, reference to the catheter is only for the convenience of writing in terms of a specific cylindrical object, and should not be considered a material limitation of the invention. However, referring to a catheter keeps present in mind the objective of having a very precise cutting device, where precision is paramount in most medical applications. Furthermore, a catheter is only one embodiment of a medical application, but which easily represents the need for precision.

The system 6 shown in FIGS. 1A and 1B is comprised of several elements including a base member

10 for supporting the structure. Coupled in sliding engagement with a vertical base member 12 is a vertically movable member 14 which has a first vertical coupling face 16 and a first horizontal coupling face 18. The vertical coupling face 16 is slidingly engaged with a base member vertical coupling face 20.

The mechanism 22 for enabling the sliding engagement between the vertical coupling face 16 and the base member vertical coupling face 20 can be any appropriate apparatus. The important consideration is that the vertically movable member 14 not be permitted to move horizontally, or the precision of the system will be compromised. Therefore, the tolerances of the mechanism 22 must necessarily be small. A good example of an appropriate mechanism 22 is well known to those skilled in the art as a crossed roller bearing slide.

The shape of the vertically movable member 14 is shown here as a small backwards "L". An alternative shape for the vertically movable member 14 is shown in FIG. 2. The member 14 is flipped over as compared to the embodiment of FIG. 1A. The important feature of the member 14 is that it provide two faces 16, 18 which can be slidably engaged to move vertically and provide a second face on which another member can slidably engage to move horizontally.

The system in FIGS. 1A and 1B is also comprised of a horizontally movable member 24 which has a spindle end 26 and a second horizontal coupling face 28. This horizontally movable member 24 is slidably engaged at its second horizontal coupling face 28 to the vertically movable member 14 at its first horizontal coupling face 18. It should be observed that the vertically movable member 14 and the horizontally movable member 24 are capable of moving independently of each other. In this way, the system

achieves two independent degrees of freedom of movement.

The spindle end 26 of the horizontally movable member 24 provides a horizontal slot 30 in which a spindle 32 is disposed. The slot 30 is generally circular to serve as a receptor for the round shaft 34 of the spindle 32. The spindle shaft 34 has disposed on a working end 36 thereof at least one circular saw blade 38. The circular saw blade 38 is disposed vertically on the spindle shaft 34, but may also be angled in other embodiments.

The spindle shaft 34 is coupled to a drive motor by gears, belts, direct drive, or any other appropriate means (not shown) which will cause the spindle shaft 34 to rapidly rotate. The drive motor (not shown) can be disposed in any appropriate location relative to the spindle shaft. In a preferred embodiment, the spindle shaft 34 is driven by a brushless DC motor through a toothed timing belt.

The circular saw blade 38 is typical of those found in the art. In a preferred embodiment, the cutting edge 40 of the saw blade 38 is coated with industrial diamonds.

The means for holding and otherwise manipulating a catheter 8 to be cut is the clamping member 50. The clamping member 50 is comprised of two major assemblies: the clamp 52 and the clamp feeding (supplying) means 54, or the device which feeds the catheter 8 to and then through the clamp 52. The clamping member 50 is also coupled to the base member 10 and disposed to hold the clamp 52 in a position for easy feeding of the catheter 8 to the circular saw blade 38.

In the preferred embodiment, the clamp 52 is of the type known to those skilled in the art as a collet clamp. A collet clamp is a slotted cylindrical clamp inserted tightly into the tapered interior of a sleeve

or chuck on a lathe to hold a cylindrical piece of work. In FIG. 1A, the cylindrical shape of the clamp 52 is visible. It is slotted in that the clamping arms 58 are separate from each other so that they can pull away from the catheter 8 when disengaging, and then securely come together around the catheter 8 when engaging.

In a preferred embodiment, a desirable feature of the clamp 52 is that it is rotatably mounted within the clamping member 50. The collet clamp 52 can then rotate so as to dispose a different portion of the surface of the catheter 8 to the saw blades 38. The mechanism for rotating the clamp 52 is shown generally at 56, and is comprised of the clamp 52 which is held in a frame which can rotate with respect to the saw blade 38.

The clamp feeding (supplying) means 54 seen in FIG. 1B is shown in this preferred embodiment to be comprised of a pinch roller assembly 60, 62 working in conjunction with a feed roller 66. As FIG. 1B should make clear, the pinch roller assembly 60, 62 feeds the catheter 8 to the clamp 52 by using friction created between two opposing members 60, 66. The upper member is the pinch roller 60. The lower member is the feed roller 66. The feed roller 66 has an axle 68 mounted in the clamp feeding means 54 so that the feed roller 66 can roll. The pinch roller 60 is disposed at the end of a lever arm 62 which pivots at a pivoting end 70. Located distally from the pinch roller assembly along the length of the lever arm is a hole 72. One end of a spring 64 is inserted therethrough, and the other end of the spring 64 is coupled at another hole 74 to the clamp feeding means 54. The spring 64 provides the tension necessary for the feed roller 64 to push the catheter 8 to the clamp 52.

Having described most of the components in a preferred embodiment of the catheter cutting assembly

6, the operation of the assembly 6 is as follows. First, the uncut catheter 8 is placed between the pinch roller 60 and the feed roller 66. This can be done by raising the lever arm 62 by stretching the spring 64. Releasing the lever arm 62 causes the pinch roller 60 to push down against the feed roller 66, with the catheter 8 disposed therebetween. A drive mechanism (not shown) is coupled to the feed roller 66 to cause it to roll and thereby push the catheter 8 toward the clamp 52. The clamp 52 should be in a disengaged position (hole through clamp is larger than diameter of the catheter 8) so that the catheter 8 can be fed easily therethrough. After passing through the clamp 52, the catheter 8 is fed sufficiently far past the circular saw blade 38 so that it is in a proper position to have an incision made in or through its surface.

When the catheter 8 is positioned correctly, the clamp 52 is engaged and the saw blade 38 is advanced to make cutting contact. Before cutting, the saw blade 38 will always be positioned in a retracted position. The retracted position is both vertically below and horizontally pulled away from the catheter 8. The first movement of the saw blade 38 is 1) horizontal advancement toward the catheter 8. This is accomplished by moving the horizontally movable member 24 relative to the vertically movable member 14 to which it is attached. The horizontally movable member 24 is moved until it has reach the depth of the incision to be made in the catheter 8. The next step 2) comprises the vertically movable member 14 moving upwards relative to the base 10 to which is coupled to thereby make the cut. The saw blade 38 is then immediately retracted by moving the vertically movable member 14 away from the catheter 8. The horizontal member is moved only when the next cut is at a different depth or when all cutting is complete.

If another cut is to be made, the collet clamp 52 is released as step 4). The catheter 8 is then fed through the clamp 52 by the feed roller 66 as step 5). The collet clamp 52 is then re-engaged in step 6) and, if necessary, the collet clamp 52 is rotated to expose a different position of the catheter 8 to the saw blade 38. The saw blade 38 is then moved horizontally if the depth of cut is to change, and then vertically to make the cut and steps 1) through 7) repeat as often as necessary until all the incisions have been made or the catheter 8 is no longer capable of being grasped by the feed roller 66 and opposing pinch roller 60.

The above description of the operation of the catheter cutting system 6 describes the different roles served by the clamp 52. When the circular saw blade 38 is making a cut in the catheter 8, the clamp 52 holds the catheter 8 steady. When the cut has been made in the catheter 8, the catheter 8 is fed through the clamp 52 by causing the clamp to disengage from around the catheter 8. After being disengaged, the catheter 8 is fed through the clamp 52 until the next incision point on the catheter 8 is in position relative to the saw blade 38. The clamp 52 re-engages so as to be disposed snugly around the catheter 8 to again prevent movement of the catheter 8 during cutting.

It should be recognized from the description above that the width of a cut into the catheter 8 is limited to the width of the circular saw blade 38. A wider cut therefore requires that the catheter 8 be advanced slightly past the saw blade 38. However, advancement does not take place while making a cut. The saw blade 38 must be withdrawn so that the clamp 52 can disengage from around the catheter 8 while it is advanced. This is necessary because allowing

cutting of the catheter 8 when the clamp is disengaged would create a useless if not imprecise cut..

Another vital component of the assembly 6 is a position sensing means. While it is now understood how the catheter 8 is cut, it is not been explained how the feed roller 66 knows when to stop feeding the catheter 8 through the clamp 52, or how far the clamp 52 needs to rotate before cutting commences. In other words, precision cutting also requires precision positioning of the catheter. Precise positioning requires sensors which can detect where the catheter 8 is in relation to the saw blade 38 and the clamp and then provide this information to some control device which coordinates movement of all components by sending the necessary signals to correctly position all of the system 6 components.

This concept is shown generally in the block diagram of FIG. 4. The catheter cutting system 6 is shown as having inputs from a control means 80 for positioning the vertically movable member 14 and shown as arrow 82, the input shown as arrow 84 for positioning the horizontally movable means 24, the arrow 86 which designates an input for controlling rotation of the clamp 52, and an arrow 88 which designates an input for controlling the feed roller 66. Two control inputs for the clamp and the spindle motor are also shown as arrows 87 and 89, respectively. The block diagram in FIG. 4 also shows a sensor means 90 for receiving position information from the system 6 as indicated by arrow 92. This information is transmitted to the control means 80 as indicated by arrow 94 so that it can be processed and the correct control signals 82, 84, 86, and 88 can be transmitted to the system 6.

There are several alternative methods for determining the position of the catheter 8 relative to the saw blade 38. These devices can all be

substituted as the sensor means 90 of FIG. 4. The first device is an electrical conduction sensing circuit 100 shown in block diagram form as FIG. 5. It is sometimes the case that the materials used in catheters 8 are electrically conductive. Furthermore, the saw blade 38 can also be electrically conductive. Consequently, bringing the saw blade 38 into contact with the conductive catheter 8 can result in the completion of an electrical circuit. By moving the saw blade 38 sufficiently slowly so as not to abruptly make contact with the catheter 8, the moment of contact can be used as a reference point so that the saw blade 38 can be moved the proper horizontal distance to make the desired cut.

FIG. 6 shows an alternative method of position sensing. In this embodiment, mechanical drag detection means is coupled to the saw blade 38. The drag detection means 102 can be coupled to either the driving means 104 of the saw blade 38, or the spindle 32 of the saw blade 38. In other words, the drag detection means 102 is any suitable device for detecting when a dragging force is encountered by the saw blade 38. For example, one device for this purpose is a torque transducer which measures the torque loading of the shaft which turns the blade 38.

FIG. 7 shows a related method of position sensing is to use a rotation detector means 106 which detects even slight partial revolutions of the saw blade 38 as the spindle is oscillated vertically and slowly advanced horizontally. With the blade 38 not spinning, rotation of the blade 38 will occur when slight contact is made between the blade with the catheter.

A final embodiment for detecting the position of the saw blade 38 relative to the catheter 8 is to use an optical detector 108, as shown in block diagram form in FIG. 8. The optical detector means 108 is

disposed such that it can detect contact between the saw blade 38 and the catheter 8. There are various optical devices which can be used to implement this detector 108.

One aspect of the invention which is related to the various sensing means 90 described above is that not only is it important to know the position of the blade, but it is also important to know the degree of wear of the blade. All of the sensor embodiments above are inherently able to compensate for the wear which the blade 38 will experience. In other words, none of the methods for determining the exact position of the blade 38 rely on an assumption that the size of the blade 38 is constant. All of the sensor embodiments 90 account for saw blade 38 wear by dynamic determination of position which is not based on a predefined size of the saw blade 38. Instead, the sensors 90 determine when contact is being made, and adjust the position of the blade 38 or the catheter 8 accordingly.

Variations of the preferred embodiment are illustrated in FIGS. 9A and 9B which show that the clamping means 52 has been modified. As can be seen in FIG. 9A, a stationary support surface 110 is provided with a slot 112 therein for supporting the catheter 8 from below. The slot 112 guides and holds the catheter 8 before, during and after cutting. Holding the catheter 8 not only allows more precise cutting, but prevents damage to the catheter 8 which might otherwise occur. A movable clamping member 114 or anvil is also provided to thereby apply force to the catheter 8 which is clamped between the anvil 114 and the slotted support surface 110. FIG. 9B also shows that the anvil 114 has a mechanism 116 which allows the anvil 114 to move vertically with respect to the support surface 110.

FIG. 10 illustrates a modification to the spindle 32 and saw blade 38 arrangement shown in FIGS. 1A and 1B. Specifically, a plurality of saw blades 38 are shown as being mounted in parallel on the same spindle 32. This also means that the saw blades 38 are necessarily coaxial. It is also preferred that the saw blades 38 have the same diameter so that no individual saw blade 38 makes a deeper incision in the catheter 8 than any of the others. However, it should be apparent that if the spindle 32 or the saw blades 38 are easily detachable from the system 6, then saw blades of varying diameters might be mounted on the same spindle 32 to achieve a consistent pattern of cuts having different depths.

FIG. 11A shows a clamp mechanism 120 which should be used in conjunction with the multiple saw blade 38 assembly of FIG. 10. The clamp mechanism 120 is capable of holding a catheter 8 in place while the catheter 8 is cut by the plurality of saw blades 38. This is accomplished by providing a clamping surface 122 having a depression or slot 124 for receiving the catheter 8. Coupled to the clamping surface is a leaf spring 126. The leaf spring 126 is comprised of several fingers 128 which force the catheter 8 to remain in the slot 124 while it is cut. Disposed perpendicular to the slot 124 and extending from the clamping surface 122 completely through the clamping mechanism 120 to a back side 136 are a plurality of slots 130 (which make clamp fingers 132) through which the saw blades 38 are extended to thereby cut the catheter 8. The fingers 128 of the leaf spring 126 are typically spaced apart a distance which is equal to the spacing between the plurality of slots 130. This ensures that the saw blades 38 do not inadvertently make contact with the leaf spring fingers 128 while cutting the catheter 8.

To allow the catheter 8 to be fed through the slot 124 in the clamping surface 122, there must be a mechanism for raising the fingers 128 of the leaf spring 126 from off the clamping surface 122. FIG. 11A shows a plurality of holes 134 through the clamping mechanism 120, one hole 134 per clamp finger 132. FIG. 11B shows these holes 134, and more importantly, the plurality of push rods 136 which extend through the holes 134 from the back side 136 of the clamp mechanism 120 to the clamping surface 122. What is not shown is a lever arm or other mechanism which simultaneously pushes the plurality of push rods 136 when the clap mechanism 120 is instructed to disengage the clamp and move the catheter 8.

FIG. 12 is an illustration of another alternative embodiment of the present invention. The vertically movable member 14 is shown having another shape which enables it to have disposed thereon two horizontally movable members 24, each having its own associated saw blade or blades 38. This embodiment enables the catheter 8 to be simultaneously cut at different circumferentially defined points on the catheter surface. This is especially useful in making cuts in catheters which having multiple incisions. for example, on diametrically opposed positions on the catheter 8.

It should be noted that while the preferred embodiment has been defined as having a horizontally movable member with the spindle for the saw blade coupled thereto, the placement of the vertically and horizontally movable members can be switched. In this arrangement, the horizontally movable member is coupled to the base member and the vertically movable member, and the vertically movable member has a spindle rotatably coupled thereto.

An alternative embodiment of the present invention uses a lever arm which is capable of

movement in at least two degrees of freedom so that it can move vertically and horizontally to position a spindle end.

Another aspect of the invention which should be clarified is that rotating the catheter is not limited to using a rotatable clamping mechanism. For example, the clamp can be non-rotatable and disengaged to enable the catheter feeding mechanism to rotate the catheter, and then reengage the clamp to make additional incisions. Furthermore, the clamp and the catheter feeding mechanism can be rotated together before additional incisions are made.

Alternative aspects of the invention include the substitution of a non-mechanical cutting instrument for the rotating blade of the presently preferred embodiment. For example, a laser can be provided for cutting through materials which are mounted on the system.

It should also be realized that rotating blades are not the only type of mechanical blade which can be utilized. Conventioned "sawing" blades can also be provided.

It is to be understood that the above-described embodiments are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the spirit and scope of the present invention. The appended claims are intended to cover such modifications and arrangements.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A system configured for forming at least one precision cut in an elongate object, wherein the precision cut is generally transverse relative to a lengthwise axis of the elongate object, said system being characterized by:

a base;

a clamp, supported by the base and configured for selectively grasping and stabilizing the elongate member in a position suitable for cutting;

a first roller and a second roller comprising a pinch roller and feed roller, the first and second rollers being rotatably supported by the base, and configured to move the elongate object in a direction parallel to the lengthwise axis, said rollers being rotatable with the elongate object around the lengthwise axis of the elongate member;

a mechanism configured for rotating the elongate object, said mechanism being supported by the base and configured to rotate the first and second rollers;

a moveable member moveably carried by the base, and

a cutting means carried by the moveable member and moveable therewith toward and away from the elongate object, the system being configured for forming at least one precision cut in the elongate object at a desired location to a desired depth.

2. The cutting system as defined in claim 1, wherein the clamp is further characterized by having at least two opposing surfaces which are movable so as to press against the elongate object which is disposed therebetween and hold the elongate object.

3. The cutting system as defined in claim 2, wherein the clamp is further characterized by a means for rotating the clamp about the lengthwise axis of the elongate member with the first and second rollers while the clamp is holding the elongate object.

4. The cutting system as defined in claim 3, further characterized in that the first and second pinch rollers comprise a pinch roller assembly disposed adjacent to, and rotatable with, the clamp.

5. The cutting system as defined in claim 4, wherein the pinch roller assembly is further characterized in that:

the first wheel is configured for supporting and forcing the elongate object to move toward the clamp when the clamp is disengaged, and the

second wheel is configured for applying a force to the elongate object to thereby hold it against the first wheel, thereby providing friction to push the elongate object toward the clamp; and

a lever arm is coupled to the second wheel and a spring is provided, coupled to the lever arm, the spring providing the force urging the second wheel toward the first wheel.

6. The cutting system as defined in claim 1, wherein the cutting means is characterized in that it is a mechanical blade.

7. The cutting system as defined in claim 6, wherein the mechanical blade is further characterized by being a rotating saw blade.

8. The cutting system as defined in claim 6, wherein the system is further characterized by a sensor configured for determining a reference point comprising a contact between the blade and the elongate object, to thereby enable precision tolerances in a depth of a cut made in the elongate object.

9. The cutting system as defined in claim 1, wherein the clamp is further characterized in that it comprises a collet clamp.

10. A system configured for forming at least one precision cut in an elongate object, said system being characterized by:

a base member;

a horizontally movable member having a spindle end, said horizontally moveable member being slidably carried by the base member;

a rotatable spindle disposed through the spindle end;

a circular saw blade, mounted on the spindle;

a drive means coupled to the spindle, configured for rotating the circular saw blade;

a clamping member coupled to the base member and a clamp disposed within to thereby enable the clamping member to engage the elongate object while the circular saw blade makes the at least one precision cut therethrough; and

a pinch roller assembly configured for rotating the elongate object and for feeding the elongate object through the clamp towards the saw blade.

11. The system as defined in claim 10, wherein the horizontally movable member is further characterized by a horizontal coupling face which is slidably coupled to the base member.

12. The system as defined in claim 11, further characterized by a crossed roller bearing slide coupling the horizontal coupling face to the base member.

13. The system as defined in claim 10, wherein the clamp is further characterized in that it is rotatably disposed within the clamping member to thereby enable the clamp to rotate within the clamping member and expose the circumference of the elongate object to the circular saw blade.

14. The system as defined in claim 13, wherein the clamp is further characterized in that it comprises a collet clamp.

15. The system as defined in claim 10, wherein the clamp is characterized by:

a slotted horizontal surface for supporting the elongate object from below; and

a movable clamping member disposed above the slotted horizontal surface for applying force to the elongate object to thereby hold it against the slotted horizontal surface while the elongate object is being cut.

16. The system as defined in claim 15, wherein the slotted horizontal surface is more specifically characterized by a single slot depression from which the elongate object cannot easily move laterally when force is being applied by the movable clamping member.

17. The system as defined in claim 16, wherein the movable clamping member is further characterized by a slot cut therein for engaging the elongate object.

18. The system as defined in claim 10, wherein the pinch roller assembly is disposed adjacent to the clamp, and is configured to feed the elongate object toward the clamp.

19. The system as defined in claim 18, wherein the pinch roller assembly is more specifically characterized by:

a first wheel for supporting and forcing the elongate object to move toward the clamp when the clamp is disengaged;

a second wheel for applying a force to the elongate object to thereby hold it against the first wheel, thereby providing friction to push the elongate object toward the clamp; and

a lever arm coupled to the second wheel, and a spring coupled to the lever arm providing the force applied by the second wheel.

20. The system as defined in claim 10, wherein the system is further characterized by a sensor configured for determining a reference point of contact between the circular saw blade and the elongate object.

21. The system as defined in claim 20, wherein the sensor is further characterized by an electrical conduction sensing circuit coupled to the circular saw blade and the elongate object, wherein the elongate object is conductive, and said circuit signalling a position controlling means when an electrical circuit is complete when the circular saw blade comes into contact with the electrically conductive elongate object.

22. The system as defined in claim 20, wherein the sensor means is further characterized by a mechanical drag detection means coupled to the circular saw blade.

23. The system as defined in claim 22, wherein the mechanical drag detection means is characterized by a rotation detector which monitors rotation of the circular saw blade.

24. The system as defined in claim 22, wherein the mechanical drag detection means is further characterized by a torque detector which monitors a change in an amount of torque required to turn the circular saw blade.

25. The system as defined in claim 20, wherein the sensor further characterized by an optical detector configured for detecting a gap between the circular saw blade and the elongate object.

26. The system as defined in claim 10, wherein the system is further characterized by a plurality of circular saw blades, wherein the saw blades are mounted in parallel and coaxially on the spindle, and wherein each of the plurality of circular saw blades has the same diameter.

27. The system as defined in claim 26, wherein the clamp is characterized by a clamping member having:

a clamping surface wherein a depression is disposed thereacross for partially receiving and holding straight the elongate object;

a plurality of slots extending from the clamping surface through to an oppositely facing back side;

a spring have a plurality of fingers disposed between the slots, the spring being coupled to the clamping surface for forcing the elongate object into the depression and against the clamping surface;

a plurality of access holes between the plurality of slots and extending from the back side through to the clamping surface; and

a plurality of push rods, a single rod disposed within each of the plurality of access holes to thereby lift the spring fingers from off the elongate object when the elongate object is manipulated.

28. The system as defined in claim 27, wherein the clamping member is further characterized by a means for pushing the push rods through the plurality of access holes when the elongate object is to be manipulated.

29. The system as defined in claim 10, wherein the system is further characterized by

a vertically moveable member, disposed between the base and the horizontally moveable member, enabling the cutting blade to be moved horizontally and vertically; and,

a position determining means configured for determining the position of the cutting blade relative to the elongate object so that the vertically movable member and the horizontally movable member can be positioned correctly for making the at least one precision cut.

30. The system as defined in claim 29, wherein the system is further characterized by a second horizontally movable member having a spindle end and a horizontal coupling face, wherein the horizontally movable member is slidably coupled at the horizontal coupling face to the vertically movable member at the first horizontal coupling face.

31. The system as defined in claim 30, wherein the system is further characterized by a spindle rotatably coupled to the spindle end of the second horizontally movable member, and having at least one saw blade mounted coaxially on said spindle.

32. A system for forming at least one precision cut in an elongate object, said system being characterized by:

a base member;

a vertically movable member slidably coupled to the base member;

a horizontally movable member having a spindle end and being slidably coupled to the vertically movable member;

at least one rotatable spindle disposed through the spindle end;

at least one circular saw blade disposed coaxially on the spindle;

a drive means coupled to the at least one spindle for rotating the at least one circular saw blade;

a clamping member coupled to the base member and a clamp disposed within to thereby enable the clamping member to engage the elongate object while the at least one circular saw blade makes the at least one precision cut therethrough; and

a pinch-roller manipulating means for rotating and feeding the elongate object through the clamp towards the saw blade.

33. The system as defined in claim 32, wherein the vertically movable member is characterized by a first vertical coupling face and a first horizontal coupling face, and which is slidably coupled to the base member at the first vertical face.

34. The system as defined in claim 33, wherein the horizontally movable member is further characterized by a second horizontal coupling face, wherein the horizontally movable member is slidably coupled to the vertically movable member at the first and second horizontal coupling faces.

35. A method of forming at least one precision cut in an elongate object, characterized by

providing a cutting device which includes a movable member having a spindle coupled thereto, a circular saw blade rotatably disposed on the spindle, a clamp for holding the elongate object while the circular saw blade makes an incision therein, and a manipulating means including a pinch roller assembly including a first roller and a second roller, and said manipulating means being configured for advancing the elongate object toward the clamp and rotating the elongate object, the method further characterized by the steps of:

(a) providing a length of the elongate object to the manipulating means for advancing the elongate object toward the clamp;

(b) causing the manipulating means to advance the elongate object toward the clamp by rotation of a roller of the pinch roller assembly;

(c) rotating the pinch roller assembly so as to rotate the elongate object about its lengthwise axis;

(d) engaging the clamp onto the elongate object;

(e) advancing the movable member and circular saw blade toward the elongate object;

(f) making the at least one precision cut in the elongate object; and

(g) retracting the moveable member and saw blade.

36. The method as defined in claim 35 wherein the method is characterized by the additional steps of:

(h) disengaging the clamp from around the elongate object;

(i) advancing the elongate object through the clamp; and

(j) repeating steps c) through g) of claim 35.

37. The method as defined in claim 35 wherein the method is characterized by the additional step of rotating the clamp with the first and second roller of the manipulating means to thereby rotate the elongate object clamped therein and expose a different portion of the elongate object to the circular saw blade.

38. A method for forming at least one precision cut in an elongate object characterized by providing an apparatus including a clamp, a pinch roller manipulation means for rotating the elongate object about its lengthwise axis and for feeding the elongate object to the clamp, and a cutting device, wherein the cutting device makes at least one precision cut in the elongate object which is generally transverse relative to a lengthwise axis thereof, said method characterized by:

(a) feeding the elongate object toward the clamp;

(b) manipulating the elongate object by at least one of the advancing and rotating motions enabled by the pinch roller manipulating means into a position which is suitable for making the at least one precision cut therein;

(c) engaging the clamp so as to securely hold the elongate object in the position which is suitable for cutting;

(d) making the at least one precision cut in the elongate object;

(e) disengaging the clamp; and

(f) repeating steps (a) through (e) until all desired cuts in the elongate object are completed.

39. A system configured for forming at least one precision cut in an elongate object substantially as described with reference to the accompanying drawing.

40. A method of forming at least one precision cut in an elongate object substantially as described with reference to the accompanying drawings.

Dated this 21st day March 2001

Sarcos, Inc.
Patent Attorneys for the Applicant:

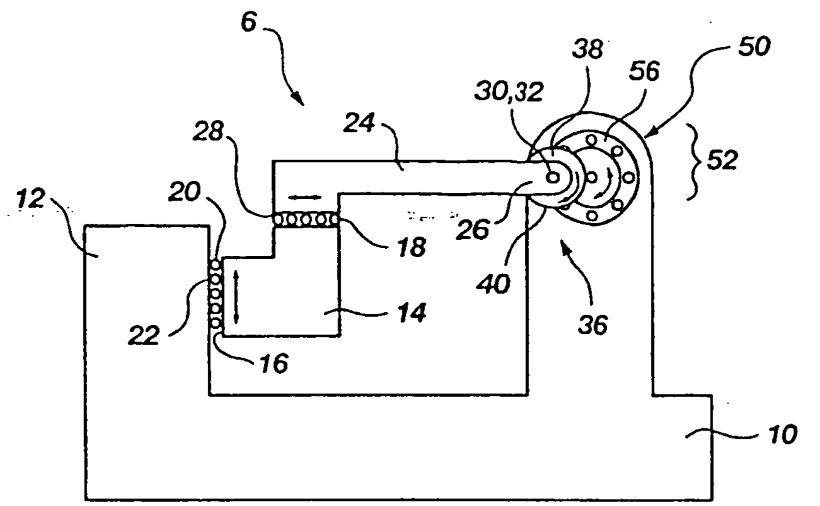


Fig. 1A

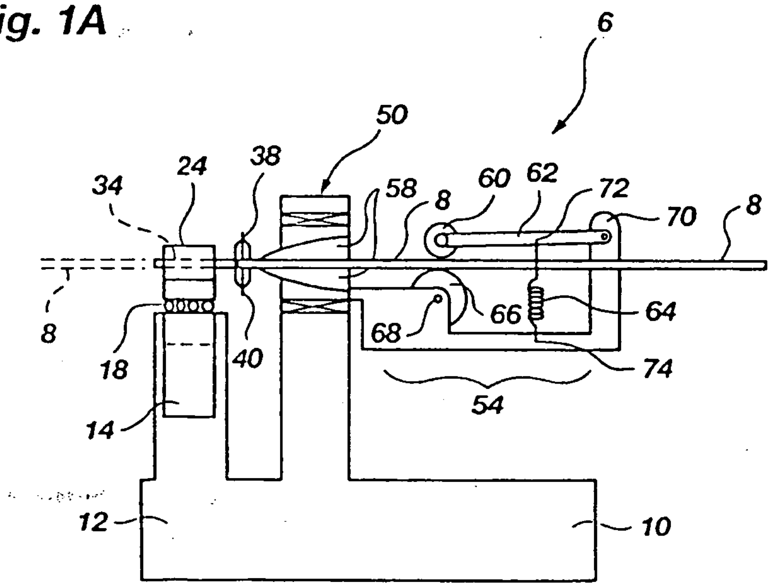


Fig. 1B

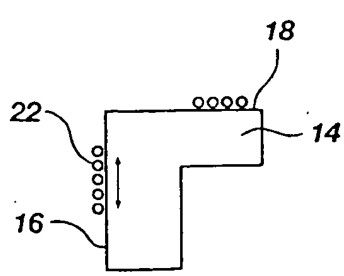


Fig. 2

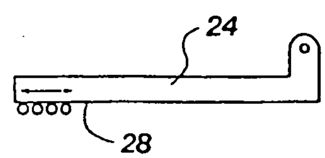


Fig. 3

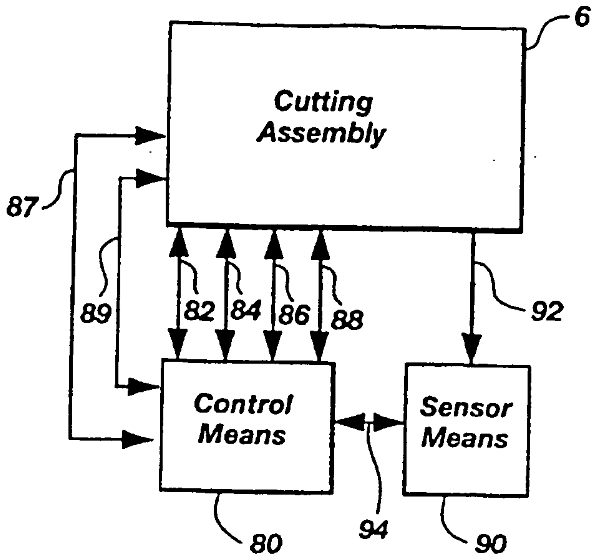


Fig. 4

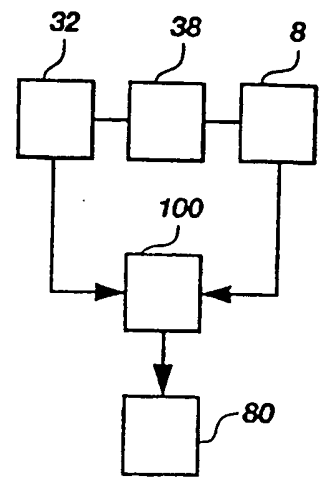


Fig. 5

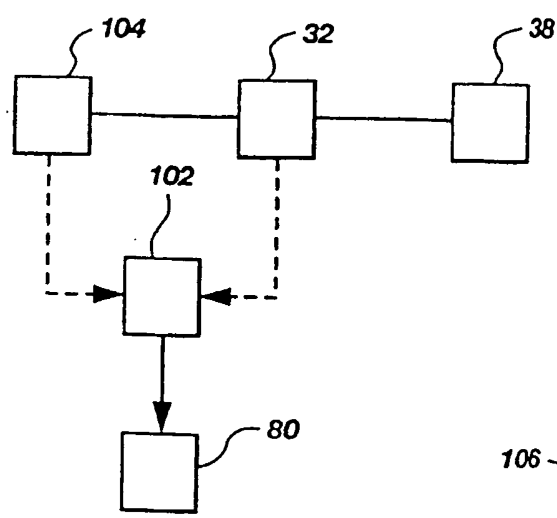


Fig. 6

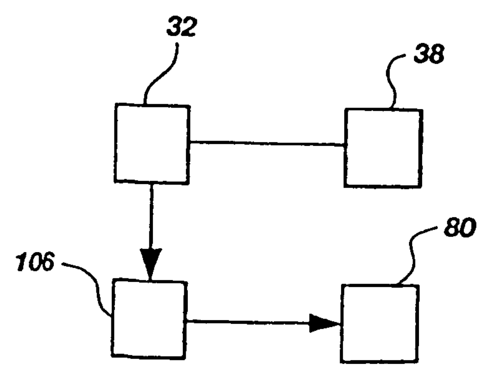


Fig. 7

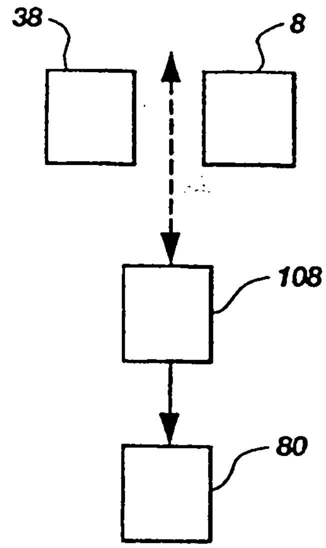


Fig. 8

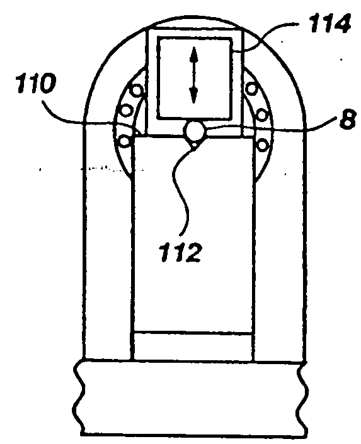


Fig. 9A

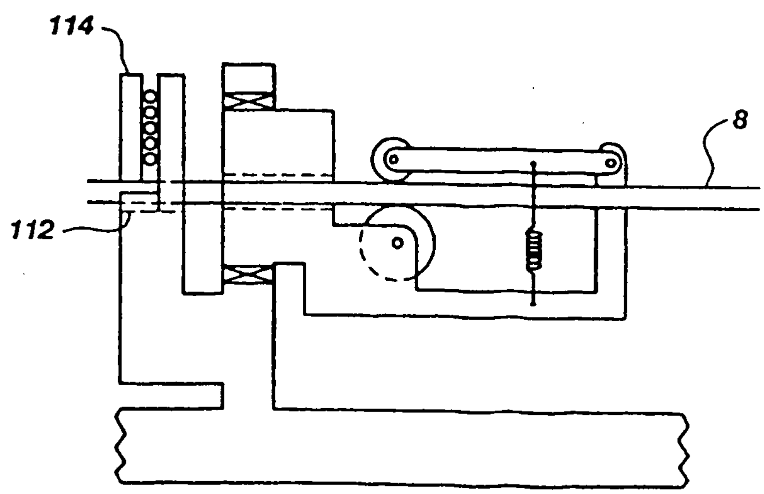


Fig. 9B

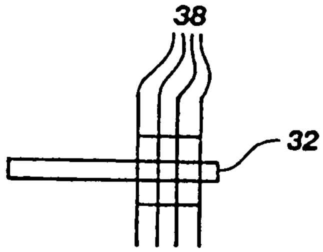


Fig. 10

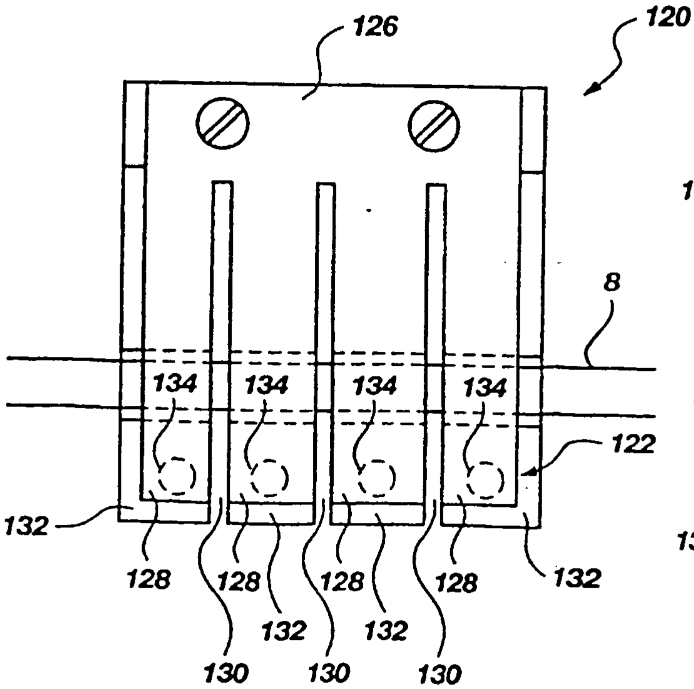


Fig. 11A

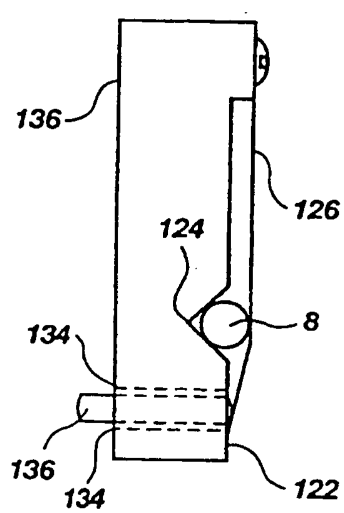


Fig. 11B

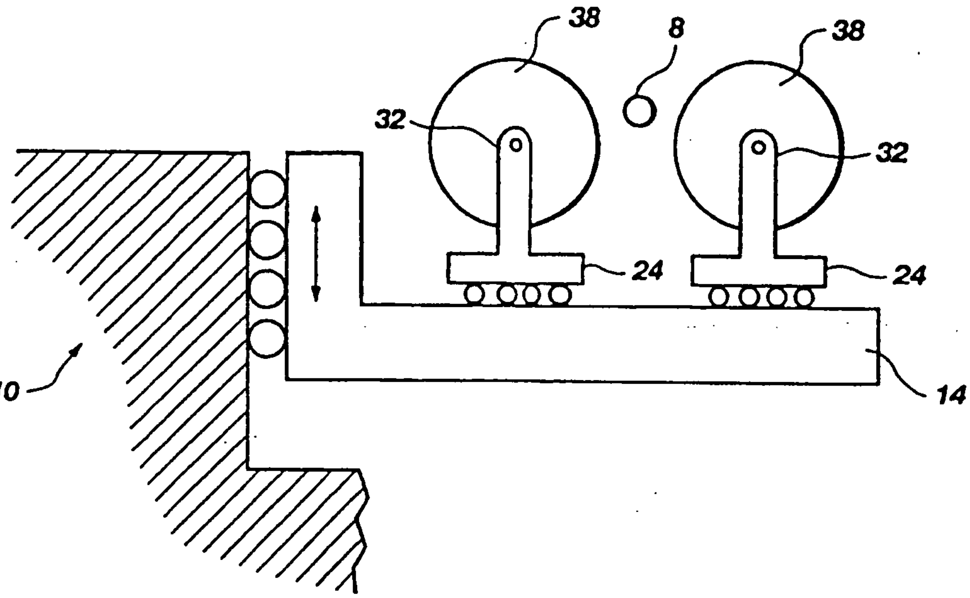


Fig. 12